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Tests of Level A Suits – Protection Against Chemical and Biological Warfare Agents and Simulants: Executive Summary

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Twelve Level A protective suits were tested for GB and HD permeation swatch testing using modified procedures of TOP 8-2-501. Agent break-through times were calculated for each suit. Vapor and aerosol agent simulant tests of suit systems were conducted to measure overall protection factors of the suits.

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Preface

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1. INTRODUCTION

In 1996, responding to Public Law 104 - 201, the Department of Defense (DoD) formed the Domestic Preparedness Program. One of the objectives was to enhance federal, state and local capabilities to respond to NBC terrorism incidents. In some cases, people who respond to an incident will use Level A protective suits to enter a contaminated or potentially contaminated area. Limited data was available concerning the effectiveness of commercially available Level A suits as protection against chemical warfare (CW) agents. Recognizing this need, the U.S. Army Chemical and Biological Defense Command (CBDCOM) established a program to test some of the Level A suit designs, using CW agents and test procedures developed for assessment of military-issue CW protective equipment. A detailed technical report was generated for each suit design tested, and a Summary Report was prepared which presented the essential results for all the suits in a single document. Because those reports are rather lengthy and technical, this Executive Summary was prepared. It is an overview of the results of the evaluation and is intended primarily for emergency response organizations and managers, to aid them in making informed decisions when evaluating suit replacements.

The suits and suit materials were tested in new, as-received condition. The effects of aging, temperature extremes, laundering, and other factors were beyond the scope of this test program. Level A suits are designed to protect the wearer from exposure to liquid, vapor and gaseous chemicals and particulates. Air is supplied by separate self-contained breathing apparatus or supplied air lines which cover and protect the eyes, nose, and mouth. These tests addressed skin protection only, and not the air supply system.

Each suit was examined in three different ways, called Swatch Tests, Aerosol Tests, and Vapor Tests. In the Swatch Tests, sample swatches were cut from selected areas (the basic suit material, the visor material, the gloves, a suit seam, the suit/visor seam, and a zipper/seam) of each suit design. These swatches were then exposed to the chemical agents Mustard (HD) and Sarin (GB), and the passage of agent through them measured. GB is a non-persistent (volatile) nerve agent, and HD is a persistent blister agent. In the Aerosol Tests, each suit design was donned by volunteer testers who carried out a prescribed sequence of movements inside a test chamber containing a controlled aerosol of corn oil, a non-toxic simulant for chemical and biological agent aerosols. Instrumentation continuously measured the concentration of simulant inside the suit. In the Vapor Tests, each suit design was donned by volunteer testers who carried out another prescribed sequence of movements inside another test chamber containing a controlled concentration of methyl salicylate (MS), a non-toxic simulant for chemical agent vapors. Instrumentation of a different design measured the total accumulation of simulant at various locations inside the suit. Each of these tests examined different aspects of the protection provided by the suits.

In the Swatch Test, test swatches were also cut from 25-mil butyl rubber gloves, MIL-G-43976, Glove Set, Chemical Protective, and exposed to the same swatch test environment as the swatches cut from the suits. These gloves are used extensively in U.S. Army operations involving contact or potential for contact with chemical agents. Because of the extensive operational experience with the gloves, the butyl rubber material was subjected to the swatch test environment for a point of comparison.

Protection provided by a suit system may vary from one unit to another, partly because variations in body size and shape affect the suit's fit; and from one occasion to another, partly because of unavoidable differences in the execution of the prescribed movements. For these reasons, each suit system design was subjected to multiple test repetitions, using a number of different sample suits, volunteer testers, and occasions. Also, different sets of prescribed movements were used for the vapor tests and the aerosol tests.

2. LIQUID CHALLENGE/VAPOR PENETRATION TEST (SWATCH TEST)

For each suit design under test, six swatches, 3 to be tested with GB and 3 with HD were taken from each of six different areas of the suit – 36 total swatches per suit design. The swatches were placed in a test fixture and a predetermined (very severe) liquid agent challenge, GB or HD, was applied to the top surface of each swatch, and the fixture sealed. Periodically, over 24 hours, gas samples were taken from below the swatches. The amount of agent vapor that had passed through the test swatch at each sampling time was measured using a highly sensitive, accurate, miniaturized gas chromatograph and sampling system known as MINICAMS.

The cumulative mass of agent, which has passed through each of the swatches at each sampling time, divided by the area of the swatch, is defined as the permeation, M_f.. Permeation is dependent on the test fixture and procedures used, as well as the properties of the agent and the swatch.

The permeation for each area of the suit tested was compared with other areas and other suit designs. Normally, continuous exposure to chemical agent would not exceed 8 hours (480 minutes) because of heat stress and fatigue, so the permeation, which occurs in the subsequent 16 hours, is of less interest.

The permeation will typically vary greatly from one area of a suit to the next, because of differences in materials and thickness. A composite average permeation value was calculated by assigning a weighting factor to the permeation value for each swatch, roughly proportional to the actual area on the suit system that the swatch represents. This resulted in a calculated overall permeation for each suit design.

HD vapors can produce skin irritation (erythema) at dosages (product of concentration and exposure time) of approximately 100 mg-min/cm^3, and GB vapors can produce incapacitation at dosages of approximately 8000 mg-min/m^3. These dosages were set as limits, and the average time to reach each of the limits was calculated using the weighted values of the swatch test

results, and it was designated the "breakthrough time" for the suit, under the specific test conditions.

For comparison, the average breakthrough time for standard 25-mil thick butyl rubber chemical protective gloves was calculated from the Swatch test data according to this method, and the results were comparable to those expected from experience with the use of actual gloves in handling the chemical warfare agents.

The calculated breakthrough times from the glove swatches and all the suit swatches are collected and presented in Table 1.

Table 1. Swatch Test Results for Level A Suits and Chemical Protective Gloves

Item	Breakthrough time, minutes	
	GB	HD
25-mil chemical protective gloves	Over 480	360
Kappler Suit Model 42483	350	150
TYCHEM 10,000 Pkg Style No. 12645	Over 480	330
Trellchem HPS suit	Over 480	Over 480
Ready 1 Limited Use Suit: Model 91	Over 480	125
First Team XE HazMat suit	Over 480	385
Commander Ultrapro Suit, Style 79102	Over 480	280
Kappler Suit Model 50660	Over 480	435
TYCHEM Style No. 11645	Over 480	Over 480
Trellchem TLU suit	Over 480	Over 480
Chemturion Suit: Model 13	Over 480	110
Chempruf II BETEX Suit	225	125
Commander Brigade: F91	Over 480	Over 480

3. SYSTEM TEST (AEROSOL SIMULANT)

This test measures the leakage of corn-oil aerosol (physical simulant for biological aerosols) into a suit ensemble. In this test, a volunteer tester donned an ensemble of a suit design (using a self-contained breathing apparatus). The tester then entered the test chamber that contained a controlled concentration of aerosolized corn oil. The tester performed prescribed exercises in the test chamber while low-volume air samples were taken from within the suit at the neck and upper arm and the corn-oil concentrations recorded continuously.

Eight different suits of each design were available in a range of sizes to fit the volunteer testers who participated in the test. A total of at least 22 test runs, and in some cases as many as 78, using at least 10 different testers, were completed for each suit design. During the test run, the tester performed each of the 8 pre-operational exercises for one minute and each of the 8 operational exercises for 4 minutes. See Table 2. The total exposure/exercise time for each complete test run was therefore 40 minutes ((8 x 1) + (8 x 4) = 40).

Table 2. Aerosol Test Exercise Routine

Phase of Test	Description of Exercise
Phase 1 (Pre-Operational) – Each exercise performed for one minute.	1) Standing still, normal breathing
	2) Bending forward and touching toes
	3) Jogging in place
	4) Raising arms above head and looking upward
	5) Bending knees and squatting
	6) Crawling on hands and knees
	7) Torso twists with hands folded on chest
	8) Standing still, normal breathing
Phase 2 (Operational) – Each exercise performed for four minutes.	1) Climb step ladder
	2) Move 3-lb. boxes from table to floor
	3) Rest
	4) Roll walls and ceiling with paint roller
	5) Bag clothes
	6) Rest
	7) Loosen bolts
	8) Move 3-lb. boxes from floor to table

The corn-oil concentration measurements from within the suit, along with the known concentration of corn-oil aerosol in the test chamber, is used to calculate the protection factor (PF) of the suit ensemble for the test conditions. Essentially, PF is a measure of the reduction in cumulative exposure to the aerosol afforded by the suit. A higher percentage of suits that pass at higher PFs means better protection.

PF for an ensemble design is affected by the fit of the suit, the design of its seals and closures, and the amount of air exhaled by the wearer during the test. The results for a given suit design often vary widely from one test run to the next, so the calculated values of PF for each suit design are compared to some PF values of interest (100,1000,2000), to make the distribution of

results more apparent. Also, because the PF is often affected greatly by the tester's movements, the two parts of each test run are analyzed and presented separately. These data were compiled and summarized for all the actual suit designs in Table 3.

Table 3. Summary of Overall Aerosol Test Results

Item	Percentage of Test Runs Where PF Met Each Hypothetical PF Threshold Value					
	100		1000		2000	
	Pre-Operational	Operational	Pre-Operational	Operational	Pre-Operational	Operational
Kappler Suit Model 42483	95.7	95.7	45.7	45.7	19.6	26.1
TYCHEM Style No. 12645	93.8	76.6	16.7	10.6	4.2	0
Trellchem HPS suit	100	100	100	100	92.3	97.1
Ready 1 Limited Use Suit: Model 91	100	100	100	100	85.4	100
First Team XE HazMat suit	91.5	89.1	87.2	84.8	78.7	82.6
Commander Ultrapro Suit, Style 79102	100	100	97.8	100	91.3	95.7
Kappler Suit Model 50660	100	100	62.5	73.9	29.2	50
TYCHEM Style No. 11645	100	100	45.4	36.4	30.4	15.9
Trellchem TLU suit	100	100	100	100	97.9	97.9
Chemturion Suit: Model 13	100	100	91.5	76.6	76.6	74.5
Chempruf II BETEX Suit	84.4	86.4	62.2	75	35.6	65.9
Commander Brigade: F91	100	100	91.7	93.2	66.7	88.6

4. SYSTEM TEST (VAPOR SIMULANT)

This test measures the leakage of methyl salicylate (MS) vapor into a complete protective garment/mask/ boot/glove ensemble. For each suit design, fourteen different ensembles, in a range of sizes, were fitted to testers and subjected to the vapor test. In this test, a volunteer tester donned an ensemble (using a self-contained breathing apparatus). The tester then entered the test chamber that contained a controlled concentration of methyl salicylate vapor and performed prescribed exercises, listed in Table 4, in the test chamber. The tester was instrumented at ten locations on the body with passive sampling devices (PSDs) which were later analyzed to determine how much MS they had adsorbed.

The MS exposure measurements from within the suit, along with the known concentration of vapor in the test chamber, is used to calculate the protection factor (PF) of the suit ensemble for the test conditions. Essentially, PF is the cumulative vapor exposure in the chamber divided by the cumulative vapor exposure inside the suit. PF, then, is a measure of the reduction in cumulative exposure to the vapor afforded by the suit, and a higher PF means better protection. The overall PF calculations also take into consideration skin area-dosage factors (amount of agent that must be adsorbed at a specific skin region to cause end-point effects multiplied by the area of skin at that region).

Table 4. Vapor Test Exercise Routine

Description of Exercise	Duration[a]
Stationary run	1 minute
Jumping jacks	2 times
Trunk twister	2 times
Bend and reach	2 times
Back stretcher	2 times
Bent knee leg lifts (left and right)	10 times
Vertical reach and grasp (left and right)	1 minute
Lifting box from ground to table and return	1 time
Squat down, kneel on one knee	3 times

[a]This entire cycle of exercises is performed twice during the 30-minute exposure

Summary overall vapor test results for each suit model tested are presented in Table 5. Note that the Vapor tests were conducted for only one suit design from each of the six manufacturers as a means of accelerating the test program and controlling costs.

Table 5. Summary of Vapor Test Results

Suit Design	Overall PF		
	Minimum	Median	Maximum
Kappler Suit Model 42483	401	1582	4917
TYCHEM Style No. 12645	193	804	5257
Trellchem HPS suit	734	1533	2578
Ready 1 Limited Use Suit: Model 91	889	1988	6166
First Team XE HazMat suit	275	1502	2767
Commander Ultrapro Suit, Style 79102	415	1110	5927

CONCLUSIONS

The test data reveals that the Level A suits tested can protect the wearers from chemical warfare agents. The duration of protection provided by each suit design will vary considerably according to how well the suit is fitted to the individual, the body motions required, and the concentration and distribution of the chemical agent in the environment.